Government Performance Results Act (GPRA) Goal 8
APM 31

Significant Research Findings:

National Human Exposure Assessment Survey (NHEXAS) Results and Databases

Scientific Problem and Policy Issues	To evaluate the health risks posed by chemical pollutants in the environment, the U.S. Environmental Protection Agency (EPA) must be able to estimate the number of people exposed to the pollutants as well as the magnitude and duration of these exposures. In the absence of actual measurements, these estimates are often based on "default assumptions," thereby introducing uncertainties into aggregate exposure estimates. Aggregate exposure refers to the total exposure of humans to single chemicals through all relevant pathways and routes. The National Human Exposure Assessment Survey (NHEXAS) studies provide real-world data on individual exposures and activities to evaluate many multimedia and media-specific risk management issues, and to improve exposure factors and models. The reports and databases described here will be useful to all Regional and Program Offices that are developing or applying exposure or risk assessment models. The study designs and protocols will aid state and federal risk assessors/managers and all researchers who plan to collect exposure measurements or make comparisons with the NHEXAS data.
Research Approach	The NHEXAS studies measured human exposures to potentially high-risk chemicals, including pesticides. Over 500 volunteers were randomly selected from three areas of the country: the state of Arizona, the greater Baltimore, Maryland area, and the EPA Region 5 states (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin). In addition, pesticide exposures for about 100 children between the ages of three and 13 were studied in Minnesota. The studies measured people's direct exposures to environmental pollutants and indirect biological indicators of exposure, or "biomarkers," in their blood or urine. The principal goals for the data analyses described in this abstract were to identify factors that explain or predict which individuals or groups are more likely to be exposed and to develop and evaluate aggregate exposure models and estimates.

As a follow-up to the NHEXAS studies, researchers from the EPA Office of Research Development's National Exposure Research Laboratory (NERL) held a workshop to discuss and document the lessons learned during the NHEXAS studies. Investigators from EPA, other federal agencies, research organizations, and universities who carried out the NHEXAS studies participated in the workshop. Extensive interviews were conducted before the workshop with key individuals from each organization to serve as a basis of discussion. Successful strategies and areas for improvement in project leadership, study design, survey operations, field sampling, analytical laboratories, database creation, and quality assurance were recorded along with recommendations for future studies.

The data from the three NHEXAS studies, including questionnaire and diary responses, results of chemical measurements on the subject's blood, urine, and residential environment, and results from the measurement of quality control samples have been made publicly available. These data are available through NERL's Human Exposure Database System at http://www.epa.gov/heds/ or http://oaspub.epa.gov/heds/hedsstart.

Results and Implications

General household characteristics and activities were examined using data from the Region 5 study to identify key factors that influence levels of residential exposure to contaminants (Bonanno et. al., 2001). Volatile organic compounds (VOCs) in the residences were associated with the storage of gas-powered devices in the home or attached garage, the use of mothballs, and the presence of carpets. Metals were linked to chipped paint, window replacement, and smoking. Construction and cleaning activities in the home were associated with higher levels of particles in the air and on the floor or carpet and of one VOC in indoor air. These results indicate that residential characteristics and activities can be used as predictors of the presence of VOCs and metals in residences.

A statistical model was constructed by Clayton and colleagues (2002) to examine anticipated relationships between exposure measurements and environmental concentrations of arsenic and lead, biomarkers (blood, urine), and questionnaire responses in the Region 5 study. Significant but weak associations were found among the concentrations, exposures, and doses for these chemicals. Relationships between the questionnaire data and the various concentration, exposure, and biomarker measurements were also generally weak. The authors suggest several ways to optimize the design of future exposure assessment studies based on the model results.

Distributions of pesticide measurements and associations between these measurements were summarized for the Minnesota Children's Pesticide Exposure Study by Clayton *et al.* (in press, 2002). Partial aggregate exposures, for the inhalation and ingestion routes only, were also estimated

using these data. Personal air exposures were closely related to indoor air concentrations for chlorpyrifos, malathion, and diazinon, while personal air atrazine and diazinon levels were more closely related to outdoor air levels (due largely to the very low levels measured indoors). The ingestion route was more important than the inhalation route as a contributor to estimates of aggregate chlorpyrifos exposure. However, the urinary metabolite of chlorpyrifos exhibited a stronger association with air measurements than with the dietary measurements.

Aggregate exposure to chlorpyrifos that was estimated using measurement and questionnaire data from adults participating in the Maryland NHEXAS study (Pang *et. al.*, 2002). Exposure from inhalation of indoor air accounted for most of the aggregate daily chlorpyrifos exposure. Concentrations in indoor air and carpet dust, and corresponding exposure rates, were highly correlated. The results suggest that analysis of aggregate exposure estimates, based on direct measurements, can help to better determine the accuracy of pesticide exposure and risk assessments.

These NHEXAS studies demonstrated that large scale exposure studies can be efficiently and effectively conducted to produce high-quality, high-quantity exposure data that can be use to reduce human risks to environmental contaminants. Overall lessons learned from the NHEXAS studies, as documented by Leovic *et. al.* (2002), include:

C large-scale *population-based* exposure studies can be planned, designed, coordinated, resourced, and implemented;
C aggregate exposures to selected contaminants can be characterized through the collection of relevant exposure samples and corresponding information;
C diverse members of the scientific community (including federal agencies, universities, regions, states, communities, and contractors) can work together efficiently and effectively to plan and conduct studies of this type;
C the rate of successful sample collection and analysis was high in most media;
C cooperative agreements can be appropriate funding mechanisms to support research;
C the extensive documentation (e.g., protocols, methods, designs, and databases) developed and evaluated for NHEXAS will be useful for designing and conducting future studies; and
C results from these studies will be useful for addressing many current science issues and for developing future hypotheses.

Specific recommendations for future studies were provided for seven topic areas: project leadership, study design, survey operations, field sampling, analytical laboratories, database issues, and quality assurance.

The NHEXAS data sets have been made publicly-accessible on the internet in formats which can be used by most commercial software packages. An abstract describes each data set and document, and a data dictionary and code table are also provided to define each data set. Extensive documentation on how the studies were conducted, including quality assurance documents and standard operating procedures for sample collection and analysis, are also available. These features provide the user with data in an easy-to-use format together with enough information to evaluate the quality and potential uses of the data. These data are available through NERL's Human Exposure Database System at http://www.epa.gov/heds/ or http://oaspub.epa.gov/heds/hedsstart

Research Collaboration and Publications

The NHEXAS analysis projects were conducted under Contracts between EPA's National Exposure Research Laboratory and Emory University, Research Triangle Institute, and the University of Arizona. The Minnesota Department of Health and the University of Minnesota participated in the Minnesota Children's Pesticide exposure study.

This research has been published in the following manuscripts:

Bonanno, L.J., Freeman, N.C.G., Greenberg, M., Lioy, P.J. "Multivariate Analysis on Levels of Selected Metals, Particulate Matter, VOC, and Household Characteristics and Activities from the Midwestern States NHEXAS." *J Appl Occup Environ Hyg* 2001; 16(9):859-874.

Clayton, C., Pellizzari, E., Quackenboss, J. "National Human Exposure Assessment Survey: Analysis of exposure pathways and routes for arsenic and lead in EPA Region 5." *J Expo Anal Environ Epidemiol*. 2002 Jan; 12(1): 29-43.

Clayton, C.A., Pellizzari, E.D., Whitmore, R.W., Quackenboss,J.J. "Distributions, associations, and partial aggregate exposure of pesticides and polynuclear aromatic hydrocarbons in the Minnesota Children's Pesticide Exposure Study (MNCPES)." *J Expo Anal Environ Epidemiol.* In press 2002.

Pang, Y., MacIntosh, D.L., Camann, D.E., Ryan, P.B. "Analysis of Aggregate Exposure to Chlorpyrifos in the NHEXAS-Maryland Investigation." *Environ Health Perspect* 2002 Mar; 110(3):235–240.

The results from the Lessons Learned workshop are summarized in:

Leovic, L., Sheldon, L., Thomas, K., Highsmith, R., Tulve, N., Robertson, G., Hammerstom, K., Quackenboss, J., Melnyk, L., Berry, M., Pellizari, E., Lebowitz, M., Ryan, P.B. "Lessons Learned from the National Human Exposure Assessment Survey (NHEXAS) Pilot Studies." Proceedings of the 12th Conference of the the International Society of Exposure Analysis (ISEA).

The measurement and questionnaire databases, metadata, and study documentation are available on the Human Exposure Database System (HEDS) website at http://www.epa.gov/heds/

Future Research

Future analyses of the NHEXAS data will be based on the projects included in the Strategic Plan for Analysis of the NHEXAS Pilot Study (EPA 600/R-00/049), which is available at

Contacts for Additional Information

Questions and inquiries on NERL's research to analyze the results of the NHEXAS studies can be directed to:

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